PINEY CREEK BRIDGE
ARROYO SECO BRIDGES
CA PFH 129-1(1)

Proposed procedure for pressure grouting
Abutment 2 Shaft 4

(Malcolm Drilling Company, Inc.)

DATE: August 7, 2000

TO: Khamis Haramy

THIS IS A FAX TRANSMITTAL FROM THE ARROYO SECO BRIDGES PROJECT OFFICE

Department of Transportation, Federal Highway Administration
Central Federal Lands Highway Division
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# of Pages, including this one: 5

Here is the contractor's Proposed Anomaly Repair Procedure for your review. I will continue to question the contractor for the data for your review.

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Attention: **Chris Sveum**
Project Manager

Regarding: **California FFH 129(1) Arroyo Seco Bridge**
Los Padres National Forest
Monterey County CA

Subject: **Anomaly Repair Procedure**
Pile 4, Abutment 2

Chris:

Cross hole sonic logging of pile 4 at Abutment No.2 (piney Creek) has indicated an anomaly from 6 to 8 meters (19 to 26 feet) below the top of the pile. While debonding of the steel inspection tube has not been totally ruled out, there is a greater concern that the concrete in this location is contaminated.

Thus in accordance with Section I, subheading 565.07B "correction of Unacceptable Drilled Shaft", MDCI has prepared this pile repair plan for your review as well as review by the FHWA. The plan outlined below has been accepted by the California State Department of Transportation (Caltrans).

CIDH Pile Repair Procedure

Low density Tremie concrete in CIDH piles is commonly the results of loss of fines during placement or the presence of foreign material in the drill hole prior to placement of the concrete. In either case, permeation grouting is often used to improve the strength and reduce the permeability of the low density material. In previous projects it has been demonstrated that permeation grouting was effective inside the neat line of the pile as well as improving native granular soils around and under the pile. These improvements of porous materials enhance the bearing capacity of the pile and the corrosion resistance.

Grouting is a process where a suspension of cementatious material is pumped under pressure into a porous material. After a period of time, the grout material hardens and becomes a permanent part of the porous material matrix. Repair of concrete is most often done with organic resin grout or cementatious slurry grout. MDCI has experienced the cement slurry grout produces a superior finished product.

As a general rule, the minimum diameter of an opening suspended cement particles will enter is 5 times the effective grain size of the cement. Using that ratio, the minimum pore diameter for ordinary Portland Cement grout is 250 microns, for Geotechnical grout it is 75 microns and for super fine grout, about 30 microns.

The following procedure is based on injecting a cementatious slurry grout composed of super fine grout into a honeycombed or washed zone in Tremie placed concrete. It is understood that the porous concrete may reach the edge of the pile and provide a pathway for the grout to enter porous material around the pile.

In soils, as little as 1% grout solids by weight in a silty sand will increase the cohesion of the material to 10 ksf and at higher concentrations the strength increases markedly. For example, if a 2 ft. zone of influence around the grout injection point is used, injection of 15 lbs per foot of hole in the grout zone will be enough to bring the cohesion of that zone up to that of a stiff clay, and if 25 to 30 lbs per foot of hole is injected, the grouted soil is similar to soft rock.

Repair Process Step Description:

1) Determine thickness and depth of zone of suspected poor quality or low density concrete.

   A. Review Gamma Ray Logs and/ or cross hole seismic
   B. Discuss test results with appropriate technicians
   C. Reach agreement on depths with drilling contractor

2) Core drill pile.

   A. Drill two, 2" diameter holes on opposite sides of the pile within the inner limits of the reinforcing steel to at least 0.5 meters below the bottom of the suspected zone of deficient concrete
   B. Log the core recovery and note concrete quality.
   C. Use core data to confirm actual locations of anomalous zones of concrete.
   D. If no deficient concrete is found, grout holes with standard cement grout and water.
   E. If deficient concrete is found continue with repairs.

3) Insert a grout packer in on of the core holes and seat it at a selected level a few feet above the top of the zone of deficient concrete

4) Inject water through the packer to test the seating of the packer and flush the grout zone.

5) Observe the pressure and injection rate during the water test

   A. If water take is above 5 gpm, or pressure does not build up, look for evidence of water return to surface. Water return may be out of the second core hole.
   B. If water take is less than 5 gpm note rate and pressure.

      a) Close injection valve and note rate of pressure loss.

   C. If water or air returns to surface in 5A above, preferable through core hole No. 2, continue water injection until steady flow rate is reached. The idea is to try and flush out contaminated concrete.
   D. If water returns around the packer, reseat it
   E. If water returns from another port plug it off
   F. If the hole fails to take water, it is interpreted to mean the concrete is satisfactory, or that the low density zone at that depth is an isolated inclusion. Stop repairs and grout core holes with standard water cement grout

6) Inject a low solid content grout mix to displace any remaining water and to permeate the finest pore openings.

   A. Select the grout mix based on water injection rate. Use 10:1 grout for injection rate less than 1 gpm/ft. Use 5:1 grout for injection rate over 1gpm/ft.

      a) Test injection rate and compute solids in lbs/minute.
      b) Observe for increase or decrease in injection rate.
      c) If water or air returned in 5 above, check the site for evidence of grout return.
      d) If grout return is found estimate the rate of return
      e) Try to plug any visible grout return path.

B. If the starting mix is 10:1, continue until refusal

C. If the starting mix is 5:1, inject two bags of grout

a) Check injection rate for increases, decrease or steady
b) If the rate decreases, continue with 5:1
c) If the rate is steady or increases, thicken the mix
d) Repeat steps 6C a through c.
Note: Some judgment on the timing of mix changes is allowed, and the mix may be diluted to extend pumping time.

If water and/ or grout returns from another hole, or from the same hole it is interpreted as evidence of open channels through the porous material. In the case where the return is from the same hole, the packer is reseated to assure that the grout is not seeping between that packer and the side of the hole. The packer may need to be lifted a few inches or a few feet in order to contain the grout in a highly porous zone. In the case where return is from another hole, that hole is a temporarily plugged while injection in the original hole is continued.

The grout injection rate and pressure are adjusted in the field to meet the conditions encountered. As a general rule the maximum injection rate is 10gpm and the maximum allowable pressure is 240 psi, but both may be reduced or pumping may be temporarily stopped to allow the grout to stiffen in case excessive grout return occurs.

Conventionally, the starting grout mix is very dilute, and the solid content is increased gradually. At some point, the rate of grout injection decreases, and at that time the grout is not thickened any more. Depending on the total amount of solids that have been injected in that port, the grout mix may be thinned to extend the pumping time, or the hole may be allowed to reach refusal naturally. Grout injection continues until the injection rate is below 20lbs per hour in any 20 minute interval while holding pumping pressure of 200 psi.

If the water injection rate measured in step 4 is less than 1 gallon per minute per foot of hole in the low density zone, the starting mix should be diluted to 10:1 water to cement by weight, and not thickened.

<u>Evaluation Of The Grouting Procedure:</u>

The distance the grout solids travel through a porous material depends on the size of the pore openings. Where the porous material is sand or silty sand, the grout solids separate from the water through filtration and sedimentation processes starting only a few inches away from the injection point. Even with very high water to solids ratios, most of the grout solids are deposited within 4 ft. of the injection point. Pumping rate also influences the distance the grout travels.

Typically, the grout mixing and pumping unit is a ChemGrout model CG-500 mixer and Moyno pump combination. High pressure Henderson plunger pumps may be an acceptable alternative.

Packers of the inflatable type, such as the Aardvark of Hany system are used for deep packer settings. Mechanical packers of the ChemGrout type or similar are used for shallow packer settings. Mechanical packers are preferred. If inflatable packers are used, they should be rated for 500 psi minimum burst or better

Pressure gauges are typically 2 inch dial type. Gauge protectors are used, but in normal grouting service, gauges are usually replaced on a two or three shift cycle. The pressure range is selected such that the anticipated working grout pressure is in the middle third of the pressure range for that gauge.

The grout mix thickening procedure is based on the size of the mixer batches. If RhocChem grout is used (25 kilogram bags), the starting mix of 5:1 is batched with 2 bags and 55 gallons of water. Using the same

fill line and increasing the grout to 3, 4, or 5 bags gives weight ratios of 3.33:1, 2.5:1 and 2.0:1 and allows for easy calculation of solids injection rates.

The depth of packer settings is not important to the grouting results. Dilution of the leading edge of the grout mix occurs if the distance between the packer and the open interval of the hole is more than about 30 feet (~10 meters) or if the initial injection rate is less than 1gpm. We anticipate the dilution zone is only about 10 ft., in a 2 inch diameter, pipe, or about 1.6 gallons of grout. Therefore, it is preferable to use a simple mechanical packer set near the top of the hole since our anomaly is anticipated to be 19 to 27 feet deep and not much dilution will occur.

Information from the water pressure test in step 5 above is valuable in select the starting mix, and evidence of water return around the pile may be used to plan the grouting operation. No water take indicates a good pile.

Step 6 A d is an important field observation. In a situation where the concrete defect is deep, and the grout path to the surface may be many feet, the volume of grout return is an indication of how much cement is being deposited between the injection point and the return point. Grouting may be interrupted or suspended if the return rate is nearly equal to the injection rate. If the return rate is low, or decreasing, the operator should thicken the grout mix and/or reduce the pimping rate to allow sedimentation and filtration of the grout to plug up the path near the injection point.

The methods, equipment and procedures outlined in this letter are derived from state of the art practices in pressure grouting. MDCI has field crews that have experience in this type of grouting. They are trained to observe all indications and changes caused by the grouting and to record them. If unexpected results occur (they often do) the field operators are capable of making adjustments.

Although I would like to be more specific about the equipment, we do not have a starting date and do not know which grout mixer and/or pump will be available. MDCI can acquire an array of packers and will start with a simple mechanical packer and will switch to inflatable types if they are needed.

I anticipate coring the pile by mid next week, depending upon the availability of a core drilling Subcontractor. Please review and accept this pile repair plan.

Feel free to contact me if you have further questions.

Thank you,
Malcolm Drilling Co., Inc.

John K. Fabish
Project Manager

CC: John M Malcolm
Ed Bucher
David Judd
Job File